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A Data Model for the Integration of the Pre-commissioning Life-cycle Stages of the Shipbuilding Product

VB-1

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ABSTRACT

This paper reports some aspects of the work being carried out on the NEUTRABAS project under the ESPRIT II European research program. The aim of this project is to specify and implement a neutral product definition database for large marine-related artefacts, covering a large part of the complete product life-cycle. The results of this research program will facilitate the effective exchange of product-related data between disparate computer-based information systems, and hence promote a movement towards product life-cycle integration. The scope of the product model being developed as the basis for this integration is described in terms of its spatial and steel structural components, together with the implications for integration with other models of outfitting and engineering systems. The model is shown to encompass the wide range of product-related data which is associated with the various pre-commissioning stages of the product life-cycle. A suitable database architecture designed to support product data exchange and full life-cycle integration based on this product model, is described and discussed.

NOMENCLATURE

AEC	Architecture, Engineering and Construction.
ASCII	American Standard Code for Information Interchange.
CAD	Computer Aided Design.
CADEX	CAD Geometry Data Exchange.
CAD*1	CAD Interfaces.
CALS	Computer Aided Acquisition and Logistics Support.
CEC	Commission of the European Communities.
ED1	Electronic Data Interchange.
ESPRIT	European Strategic Program for Research and Development in Information Technology.
IGES	Initial Graphical Exchange Specification.
IS0	International Standards Organisation.
NIDDESC	Navy Industry Digital Data Exchange Standards Committee.
SET	Standard d'Exchange et de Transfert.
VDAFS	Verband der Deutschen Automobilindustrie Plaechen Scnittstelle.

INTRODUCTION

The pre-commissioning stages in the life-cycle of large, complex engineering artefacts, of which the shipbuilding product is an example, are normally associated with the generation and management of vast quantities of complex, inter-related product data. This data is concerned with all aspects of the product including its geometry, topology, functionality, the associated production processes, production planning and control, materials, quality control and so on.

The scope and complexity of the product-related data being created and manipulated throughout the various pre-commissioning stages of the complete product life-cycle, from requirements analysis, through the various design stages and finally into production, requires that equally comprehensive and coherent data models be specified and implemented to enable the effective management and exchange of such diverse product data between the associated application areas. The need for such data models is accentuated by the tendency to use increasingly complex heterogeneous computer-based information systems at the various pre-commissioning life-cycle stages. These life-cycle stages cover activities such as marketing, conceptual design,

detailed design, drafting, materials ordering, production planning and control, scheduling, and quality control. The use of such diverse software and hardware systems presents considerable obstacles to the effective management and control of the massive amounts of data related to the product which these systems both generate and use.

In theory, a product data model could and should be extended to cover the full life-cycle of the product, from the initial feasibility studies/requirements analysis, through the design and production stages, its operation, maintenance, possible upgrading and finally its decommissioning and eventual demolition. This would ensure that all information concerning the product would be available in a consistent and system-independent form throughout the full product life-cycle and even beyond. This period may typically span more than 20 years; much longer than several computer system hardware and software architecture life-times. It is appreciated, however, that the definition and implementation of a complete product data model covering all of these aspects of the life-cycle of an engineering product as complex as a ship is an onerous task, and one which would require the commitment of a vast amount of time and effort.

This paper reports on work currently in progress in Europe on the development of a data model which will facilitate the integration of those life-cycle stages of the shipbuilding product up to its commissioning and final hand-over.

STANDARDS FOR LIFE-CYCLE INTEGRATION AND PRODUCT DATA EXCHANGE

The many, non-trivial problems associated with the management and exchange of product-related data, have resulted in the inauguration of a large number of separate, but largely complementary initiatives, looking at the information management requirements of a wide range of manufacturing industries. These initiatives have resulted in the specification of a number of standards in the area of electronic data interchange (EDI). In some cases these specifications have been implemented to provide functioning data exchange systems for a range of application areas.

Early attempts at the development of standards for data exchange were largely concerned with geometry-based information. One such standard, IGES (Initial Graphical Exchange Specification) (l), allowed for the storage and transfer of basic 2-dimensional geometry between different computer-aided design (CAD) systems in a system-independent form. Although supporting the integration of those activities which are based upon geometrical data, IGES does not offer any facilities for the representation of information regarding the topology, functionality, material characteristics, production processes and management information associated with a product, and cannot therefore be used as a vehicle for the integration of information flow throughout the the complete product life-cycle.

Standard for the Exchange of Product Data

One of the most significant attempts to circumvent the limitations of standards such as IGES is currently being carried out by a committee of the IS0 (International Standards Organisation) and is commonly known as the Standard for the Exchange of Product Data (STEP) (2). The aim of this initiative is to provide a complete representation of all of the information which can be associated with a product throughout its lifetime in a completely system-independent form. That is, the basic goal is to enable a product to be represented from the requirements definition and conceptual design stages through to production, maintenance and eventual demolition. This representation is intended to include all geometric and non-geometric data associated with that product. Information types to be represented include geometry, topology, functionality, cost, materials, strength and safety. STEP is formulated in a structure consisting of an application layer upon an implementation layer, with the former comprising the relevant, domain-specific data models, and the latter the actual implementation of these models. The EXPRESS data modelling language (3) has been specifically developed for use within the application layer.

A large number of individual data models reside within the STEP application layer, being classified as either application models or resource models. Application models, such as the shipbuilding and the AEC (Architecture, Engineering and Construction) models, address the requirements of particular application areas. Resource models, such as geometry or topology, are not generally associated with a specific application area, but provide general facilities to application models. Resource models currently nearing completion within the STEP standard include geometry, topology, solids, features, material, presentation, AEC core and tolerances. Similarly, application models nearing completion include drafting, ship structures, electrical applications and finite element analysis.

A STEP data model provides a description or specification of a domain of interest and consists of entities, attributes and relationships. Entities may be either abstract, such as a powering calculation, or concrete concepts such as a stiffener piece-part . Entities may be described by a number of attributes and referred to other entities via relationships. The data model contains descriptions and other information including the

constraints upon the value of attributes, global constraints and textual descriptions with some explanation of entities. All STEP data models are ultimately described in the EXPRESS data modelling language.

The actual transfer of data between individual applications is achieved by means of a physical file. The STEP standard allows for the use of ASCII characters only in the physical file description, and requires the format to be human readable. However, in the majority of cases it is not necessary for the developer of a model to be aware of the actual appearance of the physical file.

Other Initiatives

In addition to STEP, a number of adjunct EDI projects are currently under development, some of which are providing a significant contribution to the STEP activities. Many of these initiatives are collaborative ventures supported by the Commission of the European Communities (CEC) under the ESPRIT program of research and development.

ESPRIT (European Strategic Progmmme for Research and Development in Information Technology), founded in 1983 and currently at phase II, has included a number of projects which have been significant to the development of STEP such as CAD*I (CAD Interfaces) and CADEX (CAD Geometry Data Exchange). Many other initiatives, also related to STEP, have originated in the United States and Europe in support of a wide range of industrial interests. Examples of these are the CALS (Computer-aided Acquisition and Logistics Support), NIDDESC (Navy Industry Digital Data Exchange Standards Committee), SET (Standard d'Exchange et de Transfert) and VDAFS (Verband der Deutschen Automobilindustrie Flaechen Scnittstelle) initiatives. Further details of all of 'these initiatives can be found in **(4).**

The one common aim that all of the aforementioned initiatives share, is that of providing the means for the effective storage and exchange of product-related data between different applications in a completely system-independent form.

One other project which is making a significant contribution to the STEP initiative is the ESPRIT project NEUTRABAS (5), a project which is specifically addressing the needs of the shipbuilding industry, and one which is the subject of this particular paper.

NEUTRABAS - A NEUTRAL PRODUCT DEFINITION DATABASE FOR LARGE MULTI-FUNCTIONAL SYSTEMS

The shipbuilding industry in Europe has consistently been at the forefront of technological advancement, with massive investment in computerized systems in all parts of the technical and production areas. This application of state-of-the-art technology, as illustrated by the introduction of computerized design and drafting systems, management information systems, and advanced automated manufacturing technologies, has repeatedly highlighted the need for some means for consistently storing and transferring information in an electronic format, between the various activity areas.

This perceived need resulted in the development of a proposal for a collaborative project under the ESPRIT initiative, which would involve a team of industrialists, academics and computer scientists from four European countries. The three year NEUTRABAS project started in April 1989 and involves fifteen partners from the UK, France, Germany and Spain. The overall aims of the project can be summarised in terms of four main points, *as* indicated below :

1. The standardization of the way in which information concerning marine-related products is represented;

2. The development of standard methods for the exchange and storage of product definition data in the marine industry;

3. The specification and development of a suitable database architecture which will facilitate the exchange and storage of such product definition data; and

4. The implementation of a prototype data exchange and storage system, based on the previously defined database architecture, which will demonstrate the feasibility of a truly integrated product life-cycle.

The Anticipated Benefits of the NEUTRABAS Approach

The most obvious of the anticipated benefits to arise from the application of the NEUTRABAS philosophy is that of life-cycle stage integration. This will be achieved through the coherent and consistent storage and exchange of product-related information between different application systems. In addition to this, a number of related benefits can be perceived, as indicated below.

- **Reduced project time-scales** - The adoption of a single, carefully managed information store will enable overall project time-scales to be reduced. This will be achieved through the rigorous control of information flow and the subsequent avoidance of mis-matches in information requirement and availability at each of the pre-commissioning life-cycle stages.

- ***More effective information management*** - A single, shared information storage facility will enable the more effective management of all product-related data including security, version control and data consistency issues.

- ***Rapid information dissemination*** - The adoption of a common shared information resource will result in more rapid information dissemination among the various activities involved at each of the pre-commissioning life-cycle stages.

- ***Avoidance of data transcription*** - The exchange of information between different application systems in an electronic format will avoid the need for manual or mechanical transcription of the data, with the accompanying risk of error introduction.

- ***Improved supplier/client interface*** - In an industry such as shipbuilding, which has a high level of bought-in items in its finished product, considerable benefits will be obtained from the provision of component and equipment catalogues and specifications in an electronic format, which can be incorporated into the product definition database. This will ensure that the most up-to-date information is always available concerning items of equipment obtained from outside sources.

THE DEVELOPMENT OF A SHIPBUILDING PRODUCT INFORMATION MODEL

The main aim of the information modelling process is to develop a structured representation of the information associated with a real-world physical object, which extends over the required life-cycle stages, and also supports the required views or interpretations of the product at each of these specified stages.

According to STEP, the shipbuilding product is a specialisation of the general AEC (Architecture, Engineering and Construction) category of real-world physical products. The complete life-cycle of the shipbuilding product extends from the requirements definition/mission analysis stage, through the various design stages, into production and then on to operation, maintenance and eventual demolition. At each of these various life-cycle stages, the actual physical object being considered will normally be unchanged in the global sense, although the information associated with the product and the techniques used to represent it will vary considerably. For example, at the very earliest of the design stages, the conceptual design stage, the product will usually be described in very general terms using high-level (global) information, such as intended speed, gross capacities, main dimensions etc. As the design stage progresses, additional information concerning the product will become available and so the early global product information will be supplemented by more detailed, lower-level information.

This evolution and maturing of the information associated with the product, as it progresses through its various life-cycle stages, demands that any model of this information must be specified and developed with these life-cycle stages in mind. In the context of the NEUTRABAS project it was not considered feasible to attempt to define an information model which would support all of the product life-cycle stages mentioned previously, as this would require resources and expertise not available within the existing NEUTRABAS program. Those product stages which are considered in the NEUTRABAS product information models are associated with the pre-commissioning part of the product's life-cycle.

It has already been mentioned that the information associated with the physical product matures as the life-cycle progresses. In addition to this maturing process, the same information is subject to different points of view or intetpretations during a given life-cycle stage. For example, if a physical entity such as a deck is considered at the detailed design stage, the way in which this object is described will be dependent upon which particular design activity is being considered. The draftsman producing scantling drawings will be primarily concerned with loadings, material properties, stiffening arrangements, precise geometry and so on. Whereas the naval architect investigating flooding, stability and other safety-related characteristics of the product may consider the same entity as a simple planar element without any of the previously mentioned characteristics.

It can 'therefore be seen that different views or interpretations of the same product require different aggregations of the information associated with the product. The problems associated with developing a coherent model of the information are further compounded by the conflicting approaches used at the design and production stages of the product life-cycle. For example, design is basically a top-down modelling activity with global concepts being repeatedly decomposed into smaller information-bearing units at

subsequent stages in the design process, with the associated increase in the level of detail of information. In contrast, production-oriented information modelling follows a bottom-up strategy, with individual information units being aggregated to form larger units and eventually the complete product definition.

In view of the above points, it can be concluded that any information model of a complex physical product must not only possess the scope and structure to reflect the evolution of the associated information as the product life-cycle progresses, but must also be able to facilitate different views of the product information at each of these life-cycle stages. It is with these requirements in mind that the information models of NEUTRABAS have been developed to provide a complete and coherent representation of the shipbuilding product, throughout the relevant life-cycle stages, which accommodates both the decomposition and aggregation scenarios associated with the pre-commissioning stages of the complete product life-cycle.

Information Modelling Techniques

The NEUTRABAS product model is basically comprised of a large number of physical and abstract objects which are described by means of sets of attributes. The formal specification of this model is therefore mainly concerned with the complete and unambiguous description of these objects (entities) and attributes, together with the means by which they are interrelated to form the complete description of the product. To this end, the description of the entities and attributes and the declaration of the relationships between them is achieved in three ways. First of all, a natural language (English) description of the entities and attributes is given which explains the context in which they are used and the restrictions or rules with affect their usage. Secondly, the entities and attributes are represented in a graphical form. The technique used for this graphical representation is the Nijssen Information Analysis Method (NIAM) (6), as adopted by the ISO/STEP community. The NIAM diagrams illustrate the relationships between the various entities which comprise the model, and also specify the restrictions imposed on the relationships between the individual entities and attributes. The final method used to describe the components of the product model is the EXPRESS information modelling language. This language provides a means of generating a formal, standardized textual description of the components of the model, together with the relationships between the various entities and attributes involved.

When combined, the three methods described above provide a complete and coherent description of the product information model of NEUTRABAS which forms the basis for the implementation and testing phases of the project described in subsequent sections of this paper.

THE NEUTRABAS PRODUCT MODEL

An analysis of the form and structure of the information associated with the shipbuilding product identifies four basic views of the information which combine to give a complete description of the product throughout its pre-commissioning life-cycle stages. These four views are listed below.

1. Marketing-oriented view;
2. Management-oriented view;
3. Design-oriented view; and
4. Production-oriented view.

Clearly, a shipbuilding product model must support each of these high-level views of the product-related information in order that integration of the associated activities and life-cycle stages can be supported.

When commencing the analysis of the information to be modelled, it **is** convenient to categorize the information in terms of whether it is associated with the hull of the vessel or with the machinery and outfitting systems. This enables the information analysis in these two complementary areas to be carried out in parallel, with agreed integration points providing the means for the concatenation of the two submodels. In the context of NEUTRABAS, this approach was adopted in the product modelling process with the result that two information models were developed covering the information concerned with the hull of the vessel, and that associated with the machinery and outfitting systems. This paper is primarily concerned with the model which describes the information associated with the hull of the vessel and which covers both the steel structure and the spatial arrangement of the product.

The High-Level Product Model

In very general terms, information relating to the shipbuilding product can be placed into one of three main categories :

1. Global information;
2. Information relating to the hull; and
3. Information relating to machinery and outfitting systems.

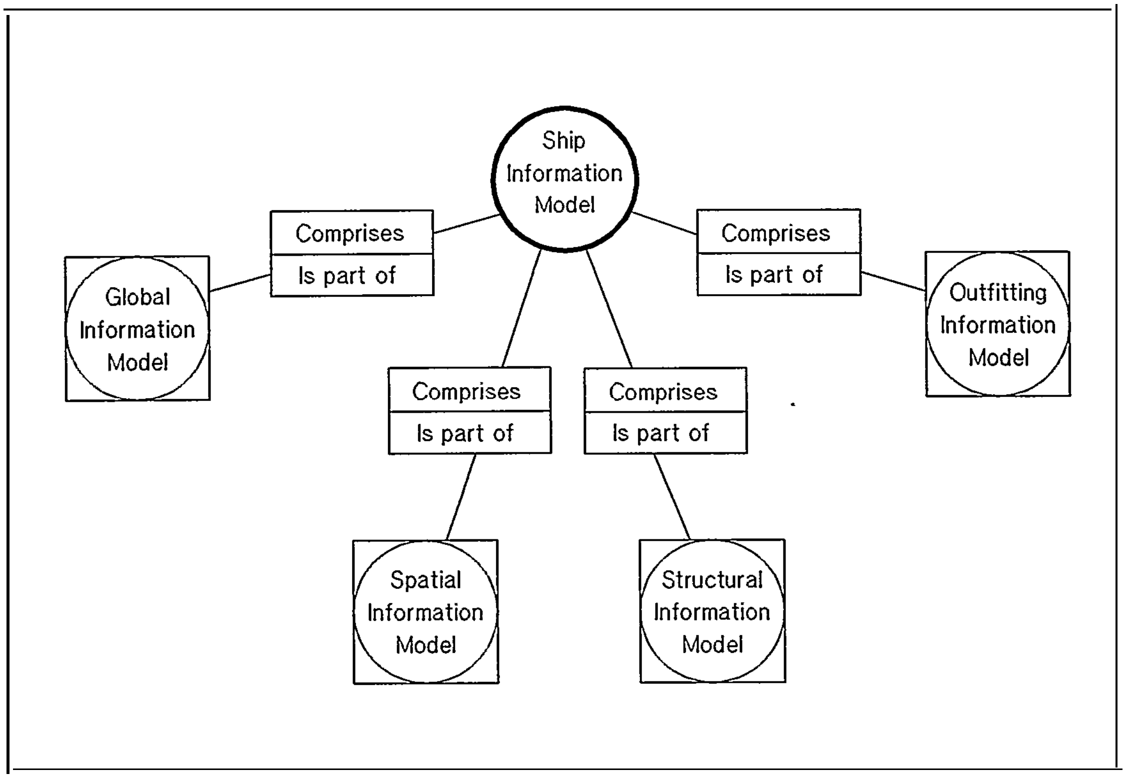

Fig.1 NIAM diagram of the NEUTRABAS high-level model.

Therefore, at the highest level, a shipbuilding product information model can be considered as comprising separate sub-models of global, hull and machinery/outfit information, as shown in NIAM form in Fig.1.

The Hull Model

As mentioned previously, a product model contains descriptions of a number of physical or abstract objects and their associated attributes together with details of their relationships with other objects. In the context of the NEUTRABAS hull model, the entities can be divided into two main categories; those associated with the representation of the structure of the the vessel and those associated with its spatial organization. Although these two groupings can be considered as distinct concepts, in reality they are mutually dependent, a fact which is reflected in the NEUTRABAS hull model.

The spatial organization model. Reference to the spatial characteristics of the shipbuilding product will be found at all of the pre-commissioning life-cycle stages. In fact, the earliest of the design-related stages, the conceptual design stage, is almost entirely concerned with the spatial aspects of the product, i.e. the definition of an acceptable general arrangement for a design proposal. This will involve the manipulation of simple planar elements which combine to form the boundaries of enclosed spaces or compartments, and the gross sub-division of the product into various functional zones, i.e. cargo spaces, machinery spaces, accommodation etc. It should be appreciated that the decisions made at this stage in the design process concerning the spatial organization of the product can have a significant effect on the overall quality of the finished product in terms of both its production and operational characteristics. Even at this early stage, the spatial organization of the product will be related to production, operational and other considerations. For example, the disposition of the main transverse sub-division members will normally be based on standard lengths of cargo holds, derived either from consideration of the size of cargo units to be carried (containers, pallets etc.), or from the maximum plate size which can be accommodated by the production facilities being considered (reduced work content etc.).

At each of the stages in the complete product design cycle, information relating to the spatial organization of the product will be required as this forms the basis for many of the associated design activities. In fact, many design activities rely solely on the availability of spatial-oriented information relating to the product. The nature of this information will change as the design process progresses from the concept stage to the detailed production-oriented design stage, reflecting the evolution and maturing of the product description.

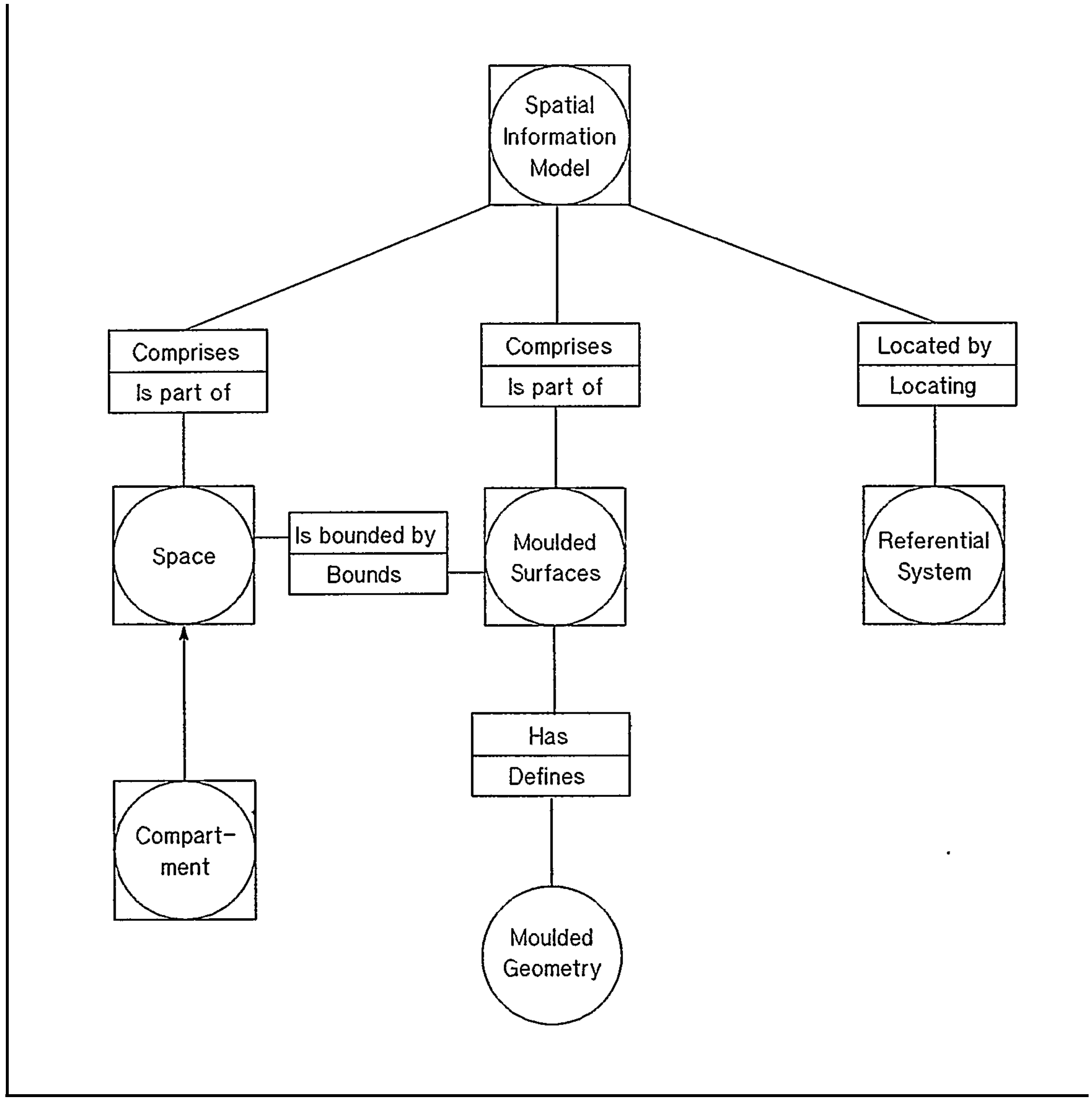

Fig.2 NIAM diagram of the spatial organisation model.

The need for the spatial organization model to reflect this evolution of the product definition through the various life-cycle stages and to support different views of the information, is therefore quite obvious.

In the context of NEUTRABAS, the spatial organization model is comprised of a number of basic elements which combine to support geometrical, topological and functional descriptions of the space-related characteristics of the complete product. These components of the NEUTRABAS spatial organization model are shown in NIAM form in Fig.2. The aim of this spatial model is to support the many applications which require space-oriented product information pertaining to the various pre-commissioning life-cycle stages.

It is to be appreciated that the spatial organization model, like all of the other NEUTRABAS information models, draws upon the information contained in the general resource models of STEP such as those concerned with geometry and topology. The integration of these general models with the spatial organization model removes the need for the explicit declaration of the associated entities within the model being described here.

As can be seen in Fig.2, the NEUTRABAS spatial organization model is basically a collection of systems which combine to describe the geometrical and topological characteristics of the internal organization of a vessel. These include the definition of the surfaces which combine to form the internal arrangement of the product, the internal enclosed spaces or compartments, and the reference systems which facilitate the orientation and location of components of the product in

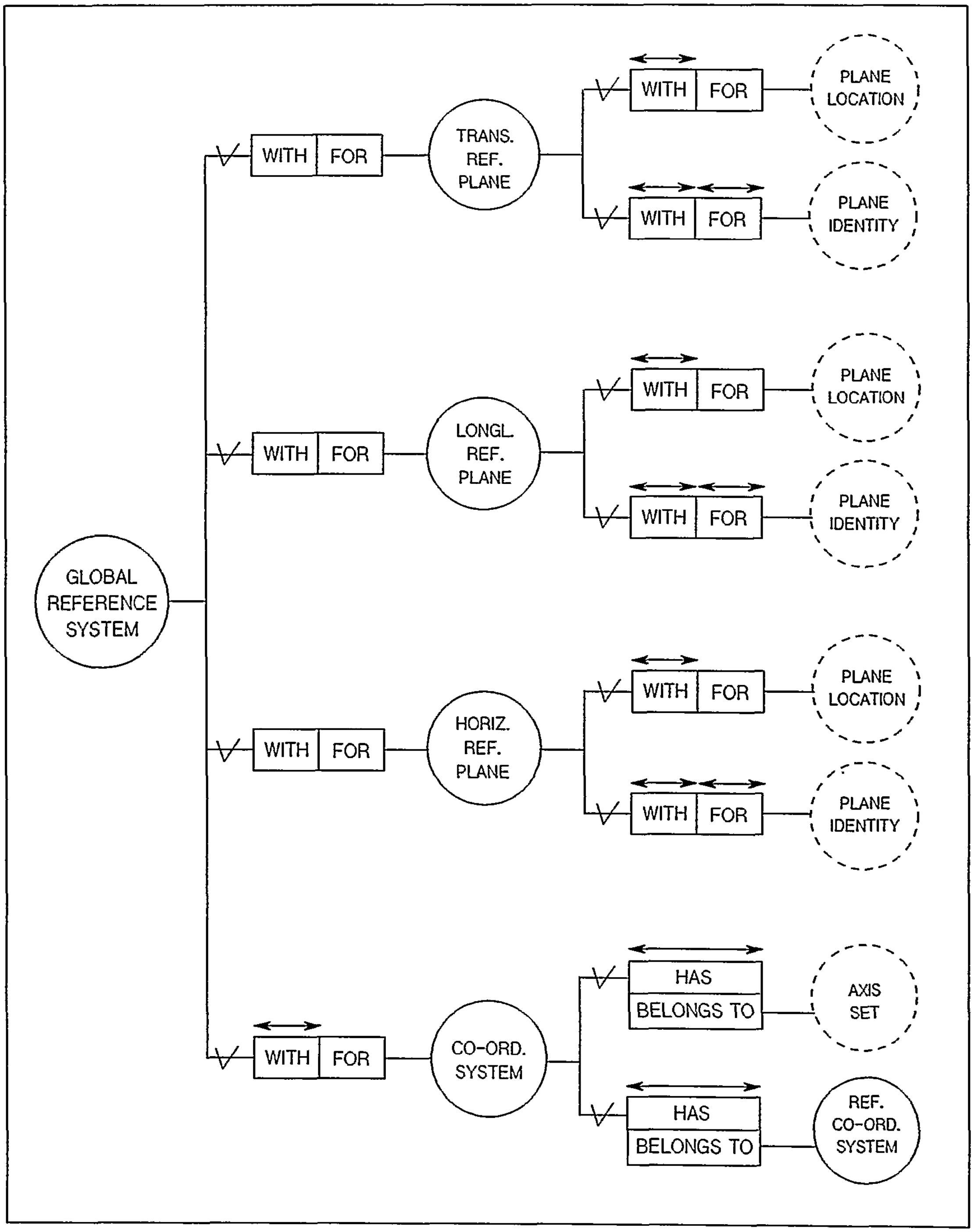

Fig.3 NIAM diagram of the global reference system concept.

three-dimensional space.

In order to illustrate the breadth and depth of the NEUTRABAS spatial organization model the following paragraphs describe a number of the components of the model in terms of the entities involved together with their associated attributes and their relationships with other entities.

The global reference system. The global reference system is perhaps one of the most important components of the spatial organization model as it provides the means for the orientation and location of all of the abstract and physical objects associated with the definition of the product. The NEUTRABAS global reference system concept is shown in NIAM form in Fig.3, and can be seen to comprise a number of elements as

listed below :

- one or more transverse reference planes;
- one or more longitudmal reference planes;
- one or more horizontal reference planes; and
- a co-ordinate system.

Transverse, longitudinal and horizontal reference planes can be associated with the location and orientation of physical entities such as frames, bulkheads, decks and so on, or abstract entities such as the boundaries of functional zones. The co-ordinate system component is itself comprised of two separate parts; a reference co-ordinate system and an axis ***set.*** This reference co-ordinate system has associated with it a global origin and its own axis set. The global reference system concept is shown diagrammatically in Fig.4.

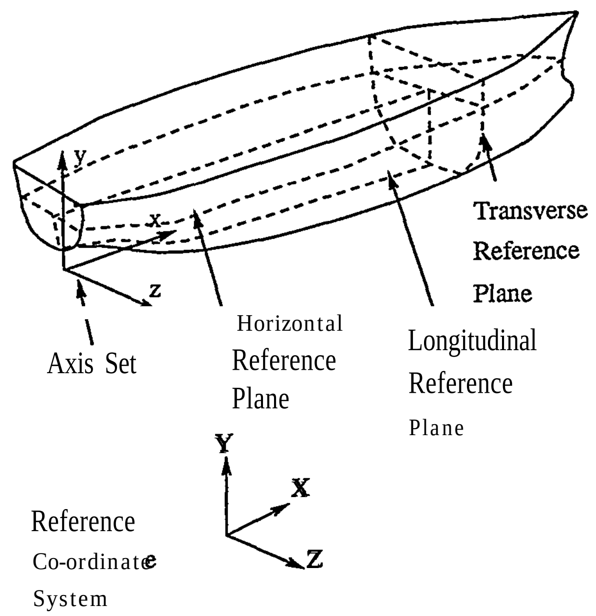

Fig.4 Diagrammatic representation of the global reference system concept.

Internal compartmentation. The spatial organization model, as its name suggests, **is** also concerned with the representaion of the internal enclosed spaces on a vessel. This representation requires the introduction of the concepts of spaces, compartments and moulded surfaces. Moulded surfaces are non-structural boundaries within the overall envelope of the product, which may provide the topological and geometrical references for associated structural boundaries. Monlded surfaces may also form part of the boundaries of physical or hypothetical enclosed spaces within the internal arrangement of the product. A variety of means can be used to define these surfaces including a variety of mathematical techniques such as the Bezier and B-spline formulations. The NIAM representation of the moulded surface concept is shown in Fig.5, which also indicates the various attributes which are associated with a particular occurrence of a moulded surface.

As mentioned above, moulded surfaces can define the boundaries of the internal enclosed spaces on a vessel. These spaces can either be hypothetical sub-divisions of the vessel, as in the case of a functional sub-division, or physical compartments used for the carriage of revenue-earning material or material required for the effective operation of the vessel such as fuel oil and water. The compartment concept is shown in NIAM form in Fig.6, and diagrammatically in Fig.7. Fig.6 shows the various types of compartments which can be found on a vessel, with the attributes which can be possessed by any compartment being shown in NIAM form in Fig.8, although it should be appreciated that particular types of compartments will have additional attributes which are peculiar to them.

As mentioned previously, the spatial organization model is closely related to that of the structural organization as it provides references for the location and orientation of the associated structural components. Additional details of the NEUTUBAS spatial organization model can be found in (7).

The structural organization model. The NEWTRABAS structural organization model is largely based upon a top-down analysis of the information associated with the representation of the structural components of the shipbuilding product. The structure of the model is based upon the repeated decomposition of the information-bearing units into their constituent parts until the required level of granularity or detail is achieved. This approach can be compared to the overall design process where high-level representations of the product are repeatedly refined until the complete product is defined in terms of individual piece-parts and components. This top-down view of the product may be representative of the design process, but is in direct opposition to the normal production-related view which tends to follows a bottom-up approach where individual piece-parts and components are aggregated to form sub-assemblies, assemblies, units, blocks and eventually the complete product. Therefore, in order to support the information requirements of the production-related life-cycle stages, the NEUTRABAS structural model has to support both the decomposition and aggregation views of the product.

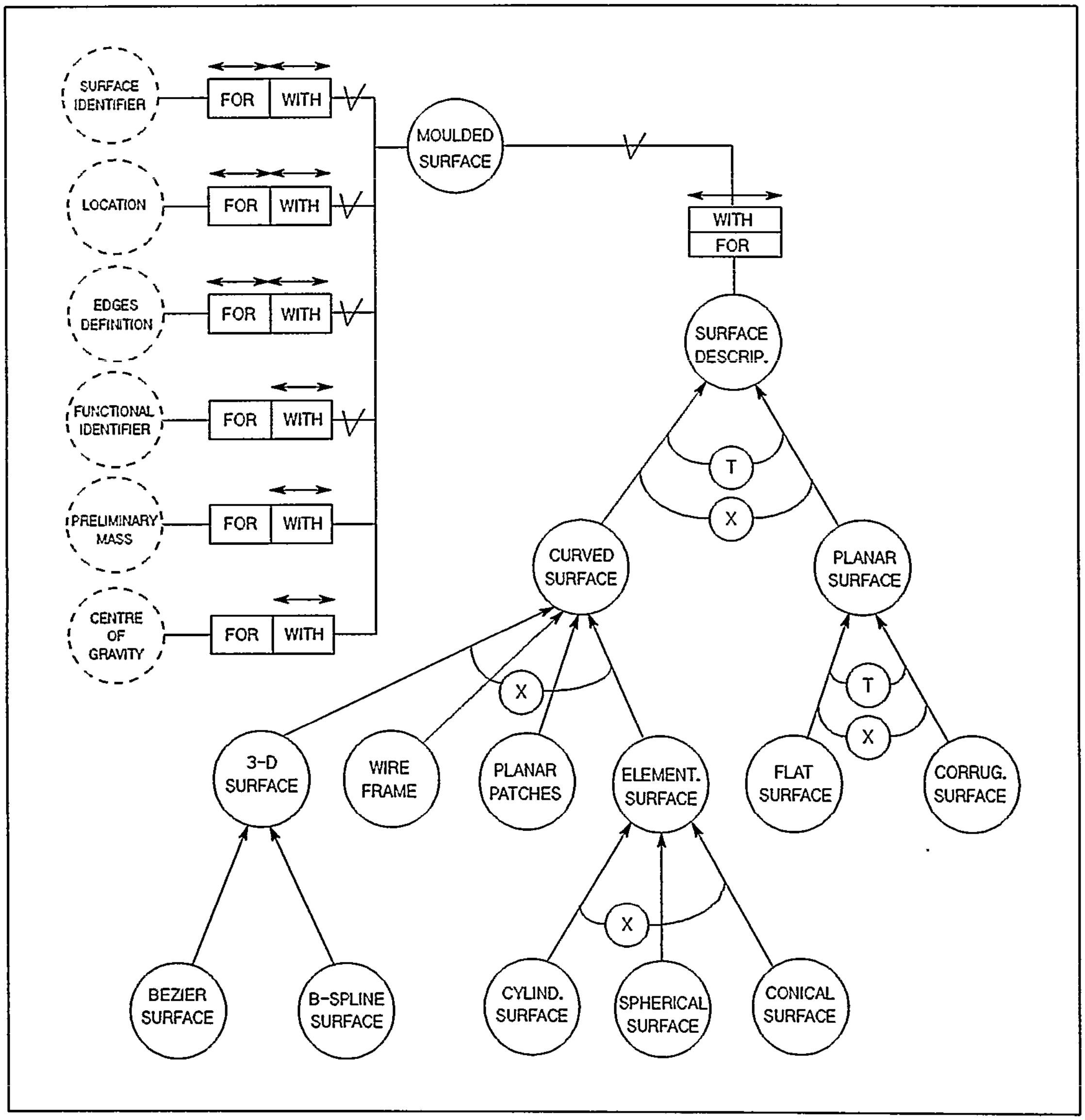

Fig.5 NIAM diagram of the moulded surface concept.

The generalised NEUTRABAS structural organization model is shown in NIAM form in Fig.9. The diagram shows that the structural system of the shipbuilding product is considered as comprising a number of non-overlapping structural elements, where each of these structural elements corresponds to a functional zone of the vessel, i.e. a double-bottom region or a main engine compartment. These individual structural elements are composed of a number of pre-fabricated blocks which are themselves made up of pre-fabricated sub-blocks or units which contain assemblies of plate and stiffener piece-parts. This decomposition is illustrated in NIAM form in Fig.10, and shown diagrammatically in Fig.11. It can be appreciated that this type of representation of the information associated with the structure of the vessel is predominantly a production-related view of that product as these pre-fabricated blocks and sub-blocks are the primary outputs of the various production processes. However, the general model also incorporates a different view of the structural representation of the product, one which is associated with the various design stages. This design-related view considers the structural elements to be comprised of a collection of primary sub-structures which correspond to the major plate panels together with their associated stiffening members. These plate panels represent the major structural entities of the vessel such as complete decks, bulkheads and the outer shell. This type of representation is comparable with the view often used at the design stages where the structural arrangement of complete decks or bulkheads are considered without regard for the eventual sub-division of the entities which is required for the production processes, and is shown in NIAM form in Fig.12.

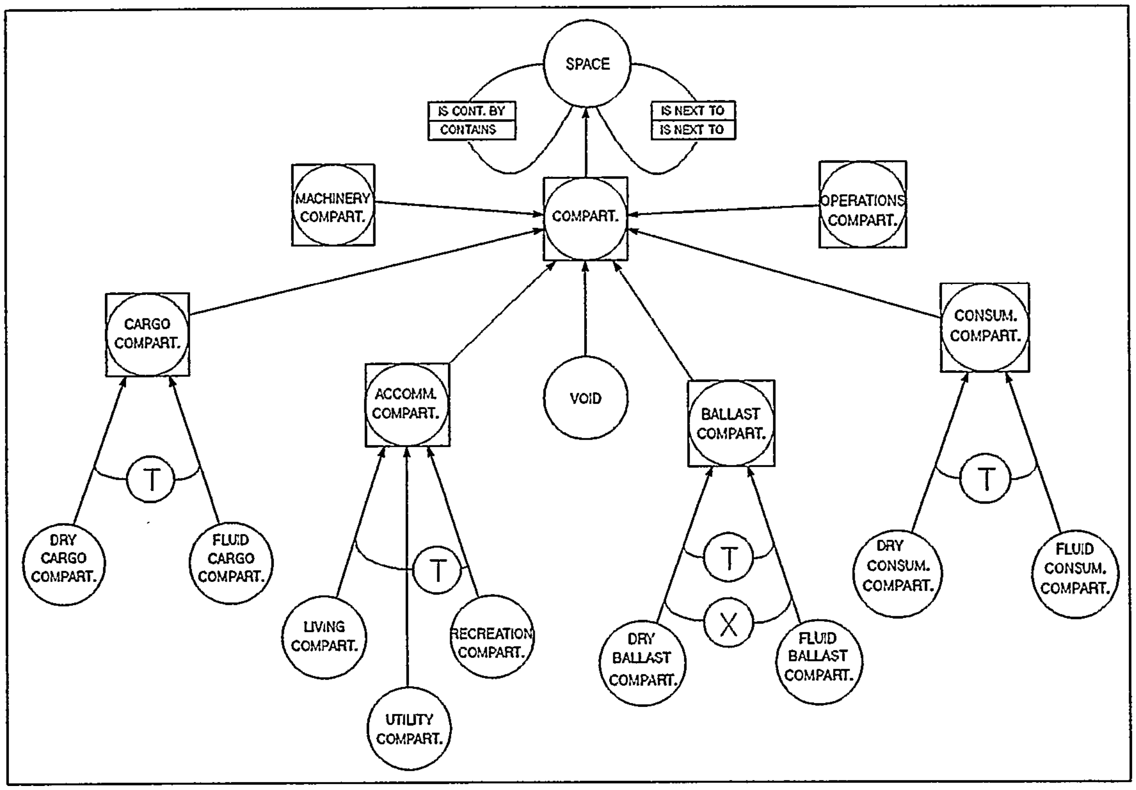

Fig.6 NIAM diagram of the compartment concept.

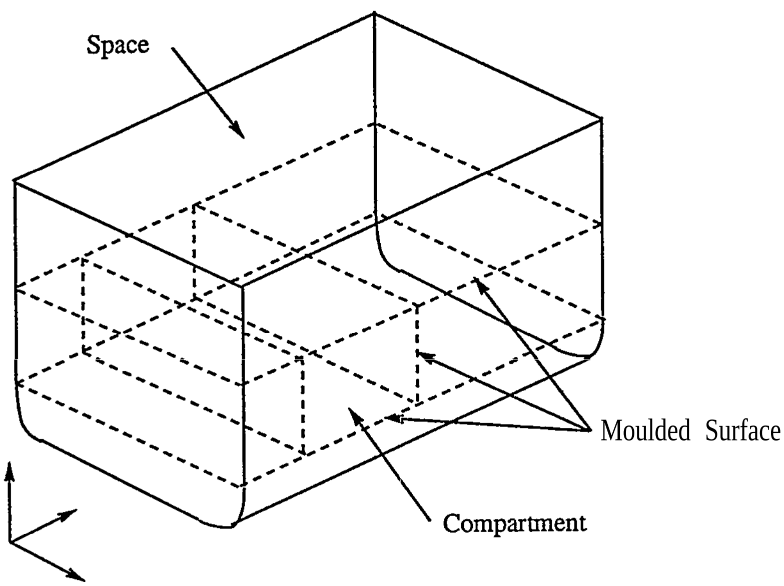

Fig.7 Diagrammatic representation of the compartment concept.

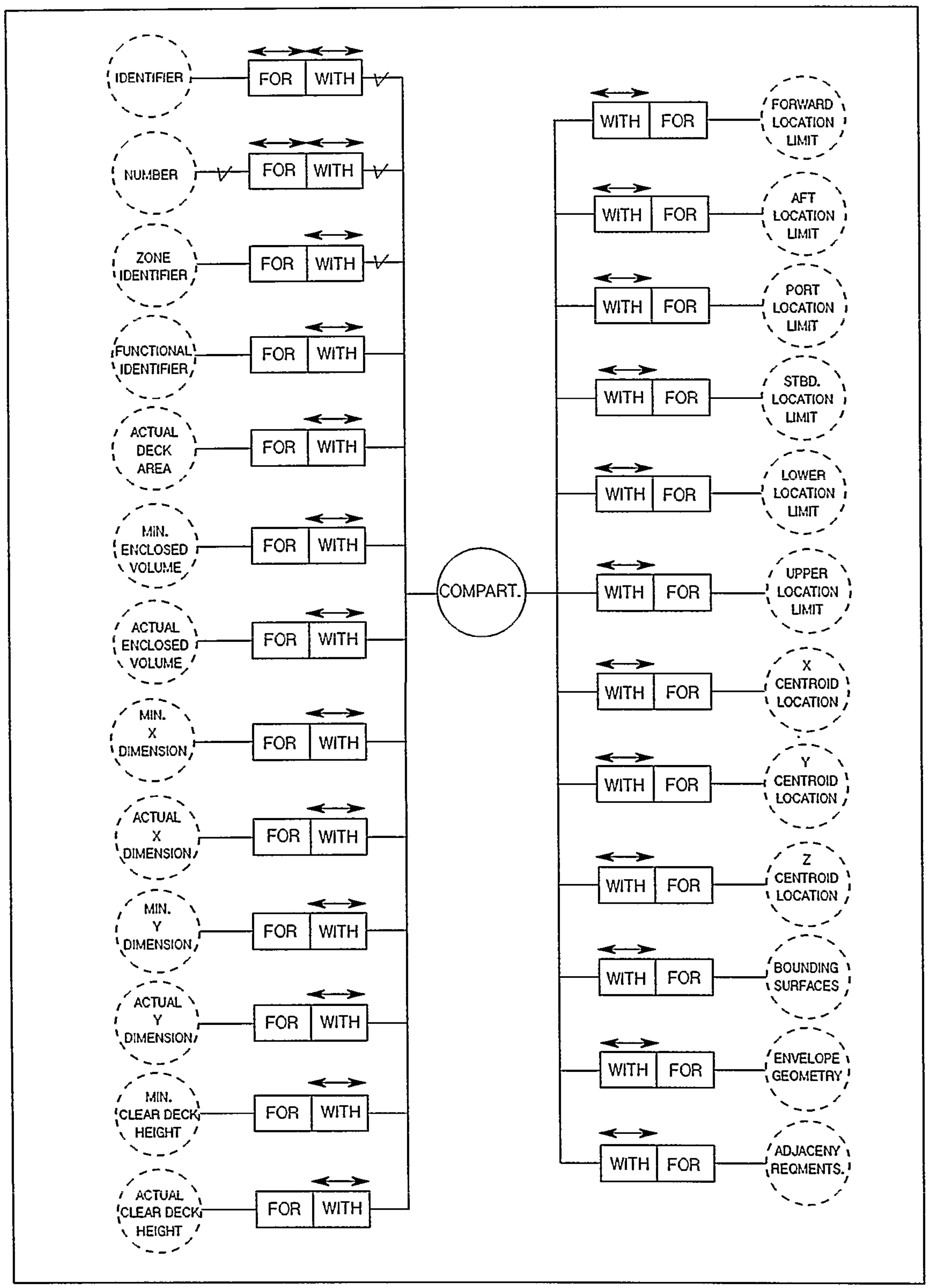

Fig.8 NIAM diagram of the compartment concept and attributes.

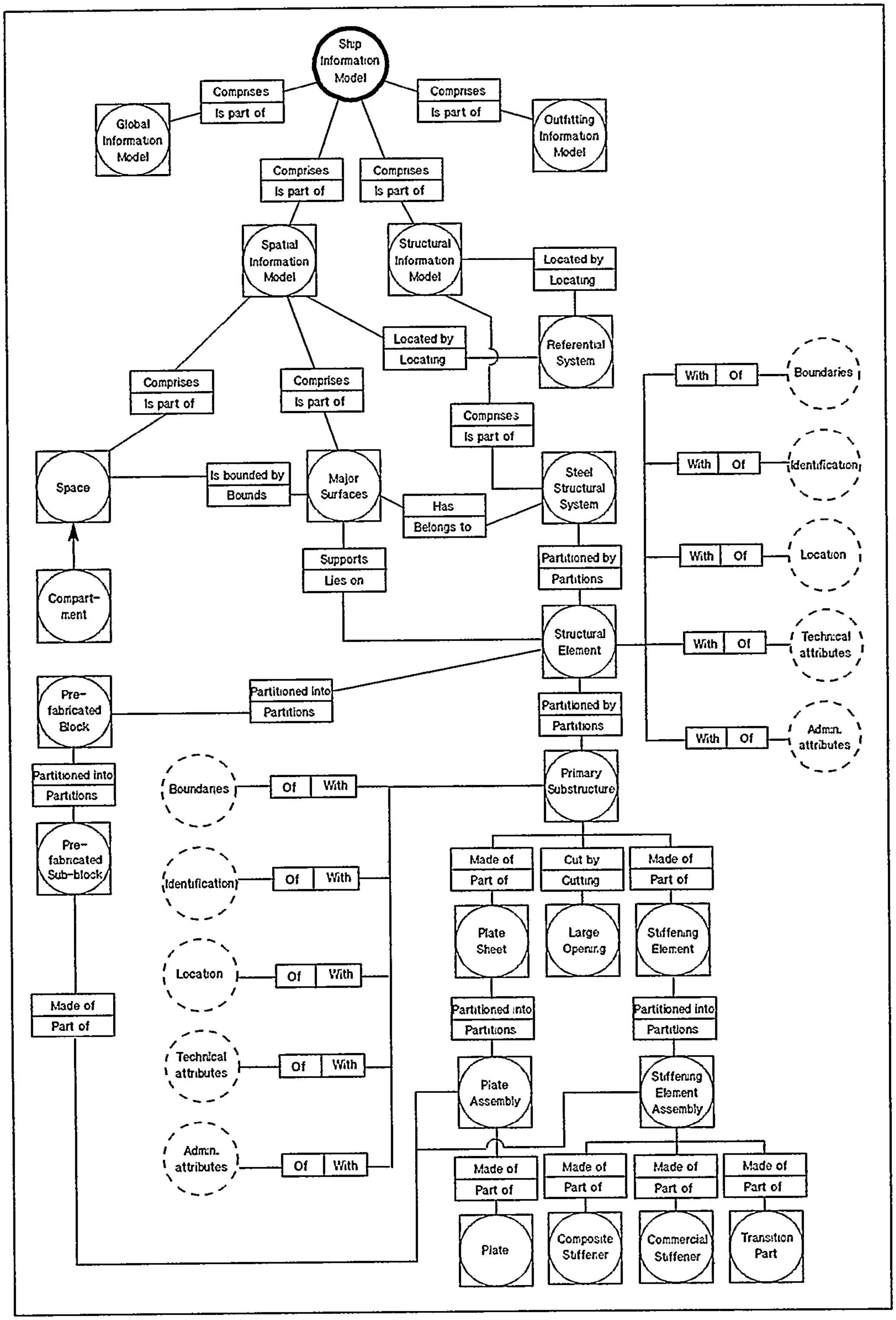

Fig.9 NIAM diagram of the general structural model.

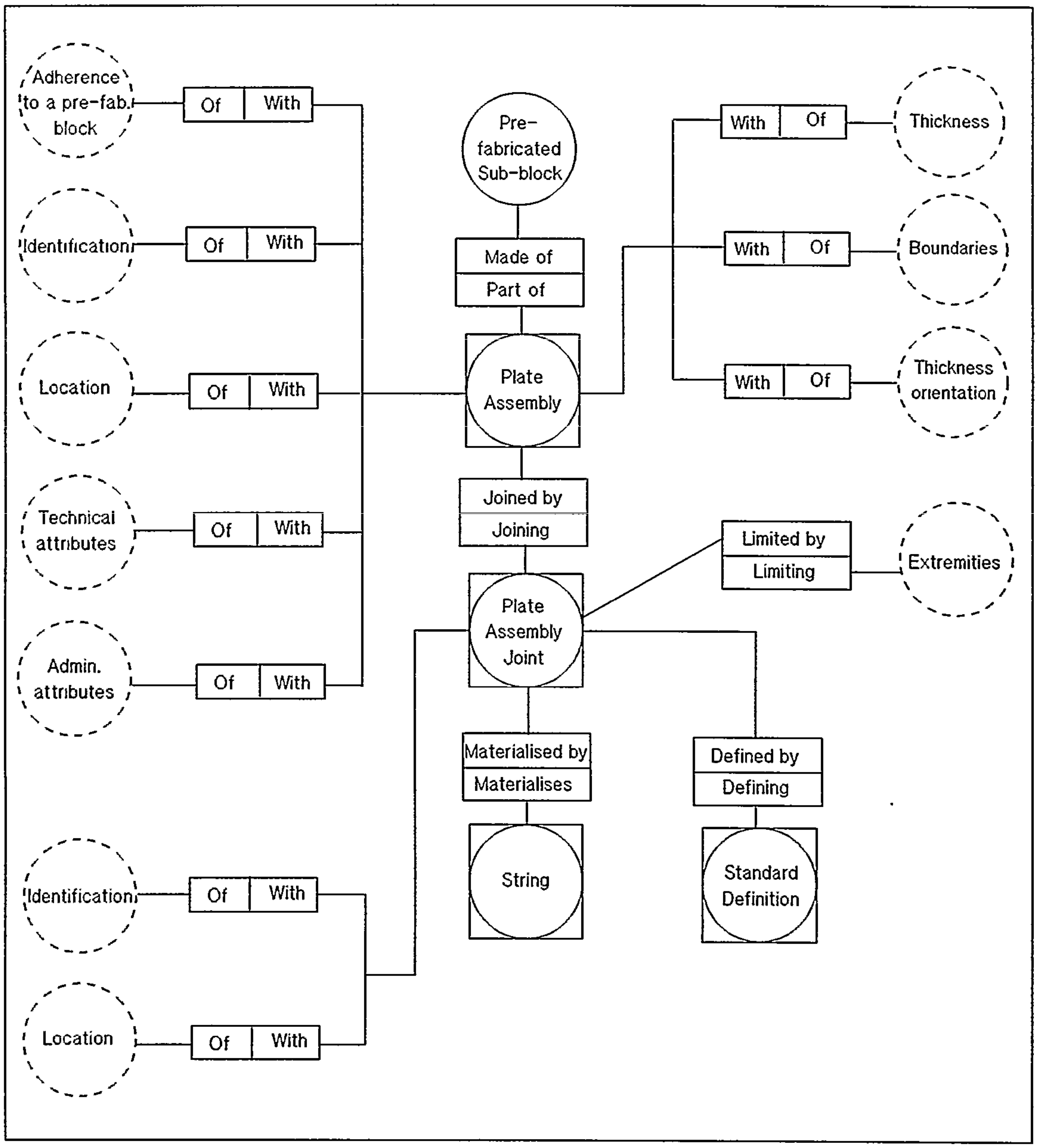

Fig.10 NIAM diagram of the sub-block concept.

The NEUTRABAS structural model has been developed so as to support both of the major views of the product which are associated with the pre-commissioning life-cycle stages, i.e. design and production. The complete model defines all of the information which can be associated with the structural system of the product including information such as the type and grade of materials, the weights and centres of parts and assemblies, details of welding procedures, and production management information, as well as information concerning the precise geometry and scantlings of individual parts and assemblies. Further details of the structural model can be found in (8).

Model Integration

The previous sections have briefly described a few of the components of the NEUTRABAS hull information model. The complete hull model provides a comprehensive definition of the type and structure of the information which can be associated with the hull part of the shipbuilding product. It should however be appreciated that the hull model is only one part of the complete description of the complete product, and that the various systems which are installed in the hull such as HVAC, electrical, pumping and the various machinery systems, are of equal importance in the specification of the complete shipbuilding

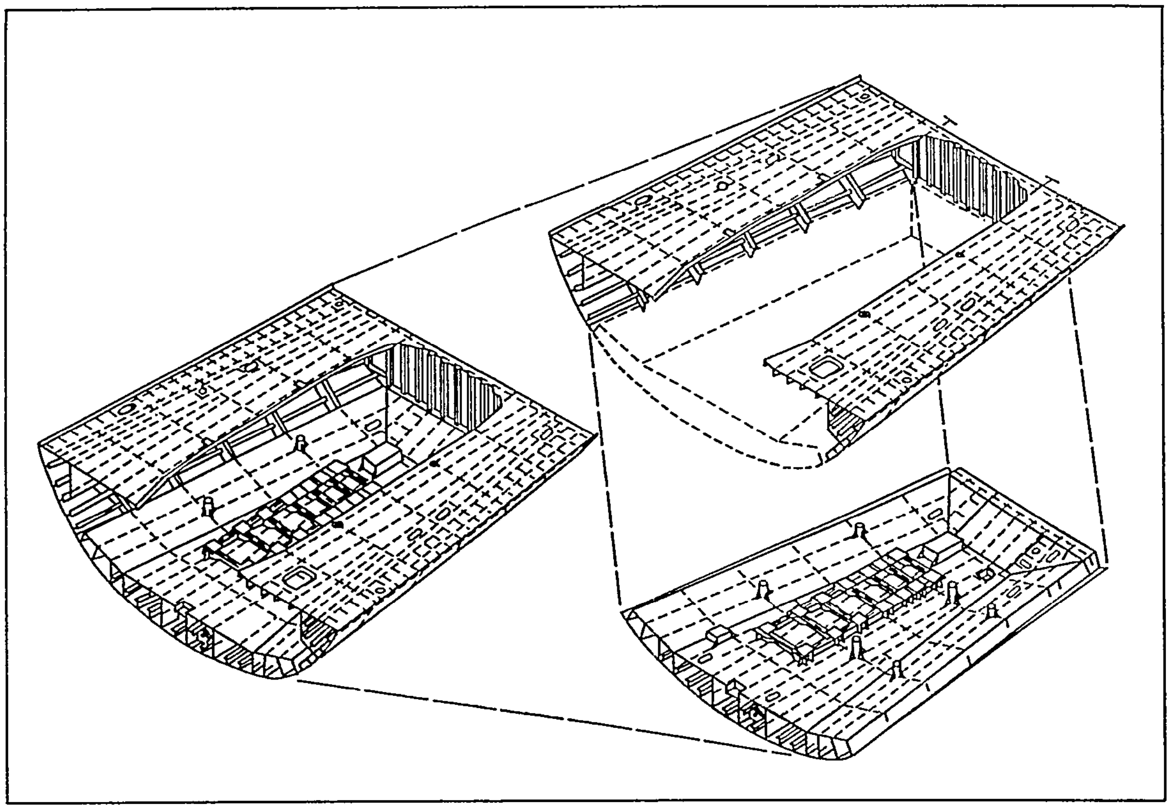

Fig.11 Diagrammatic representation of the sub-block concept.

product model. The machinery and outfitting systems model is fully described in (9). In addition, the various resource models defined by STEP have to be integrated so as to provide access to descriptions of entities dealing with topics such as geometry and topology.

The integration of these separate sub-models into a single product model is currently receiving considerable attention within the NEUTRABAS project, as it **is this fully** integrated model which will form the basis for the implementation of the product definition into a working data exchange and storage facility.

THE NEUTRABAS SYSTEM ARCHITECTURE

As previously stated, the NEUTRABAS project is different from many of the related activities in that it will be taken beyond the formal specification stage and will achieve partial implementation. In order to reach this implementation phase, a significant part of the effort associated with NEUTRABAS has been devoted to the specification and implementation of a suitable system architecture, as described in (10), which will facilitate the effective management and transfer of product data in the shipbuilding industry context. A brief description of the main features of the NEUTRABAS system architecture is given in the following sections.

Requirements of the Proposed Architecture

When considering a suitable system architecture for the NEUTRABAS project, a number of significant requirements were identified, as indicated below.

- The system would have to be hardware and software independent as the typical shipbuilding product life-cycle is in excess of 20 years; a period far exceeding the current and anticipated life-spans of both computer hardware and software.
- The system would have to be capable of storing both information models and data models as the storage of data only in a neutral format is of no real value. The semantics of the relationships between the data items will also need to be defined and stored.
- The system would need to be independent of the application area. As NEUTRABAS is intended to cover all of the pre-commissioning stages of the product life-cycle, it has therefore to be capable of storing information together with the view or

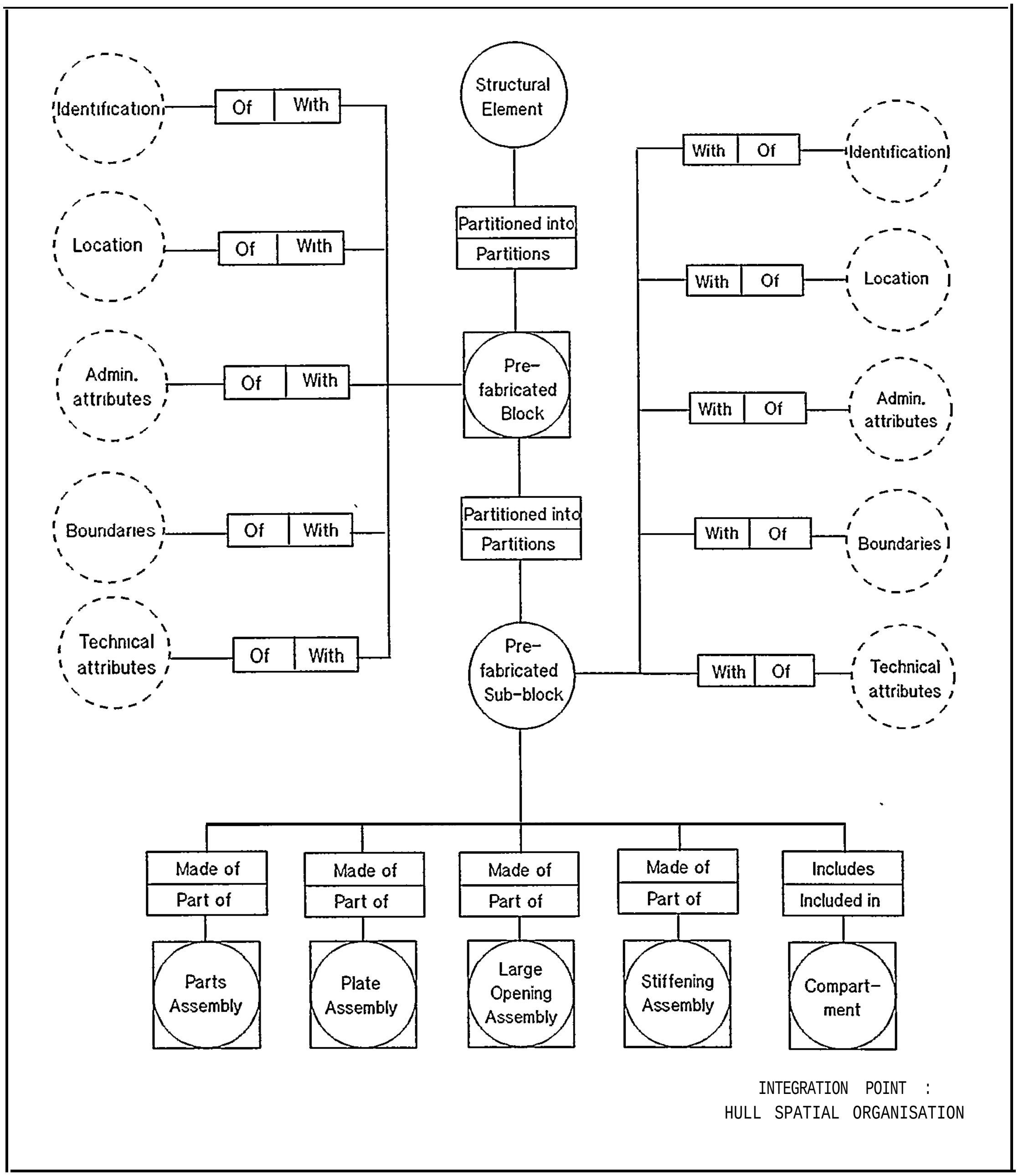

Fig.12 NIAM diagram of the structural element concept.

interpretation of that information for any application system at any stage in the product's pre-commissioning life-cycle.

The system would have to be dynamic as NEUTRABAS will be able to share information between large number of application systems and users, and must therefore have the capability to interrogate and update the database asynchronously. Equally, it must allow for the evolution of the information model itself.

The Proposed Architecture

The proposed main components of the complete NEUTRABAS implementation environment are shown diagrammatically in Fig.13. The NEUTRABAS system architecture is intended to provide all of the means necessary for the creation of schemata, from previously defined product information models, for a variety of database management system architectures; the facilities needed for the effective management of product data contained in these databases; and the various interfaces which will permit various application systems to communicate with this neutral

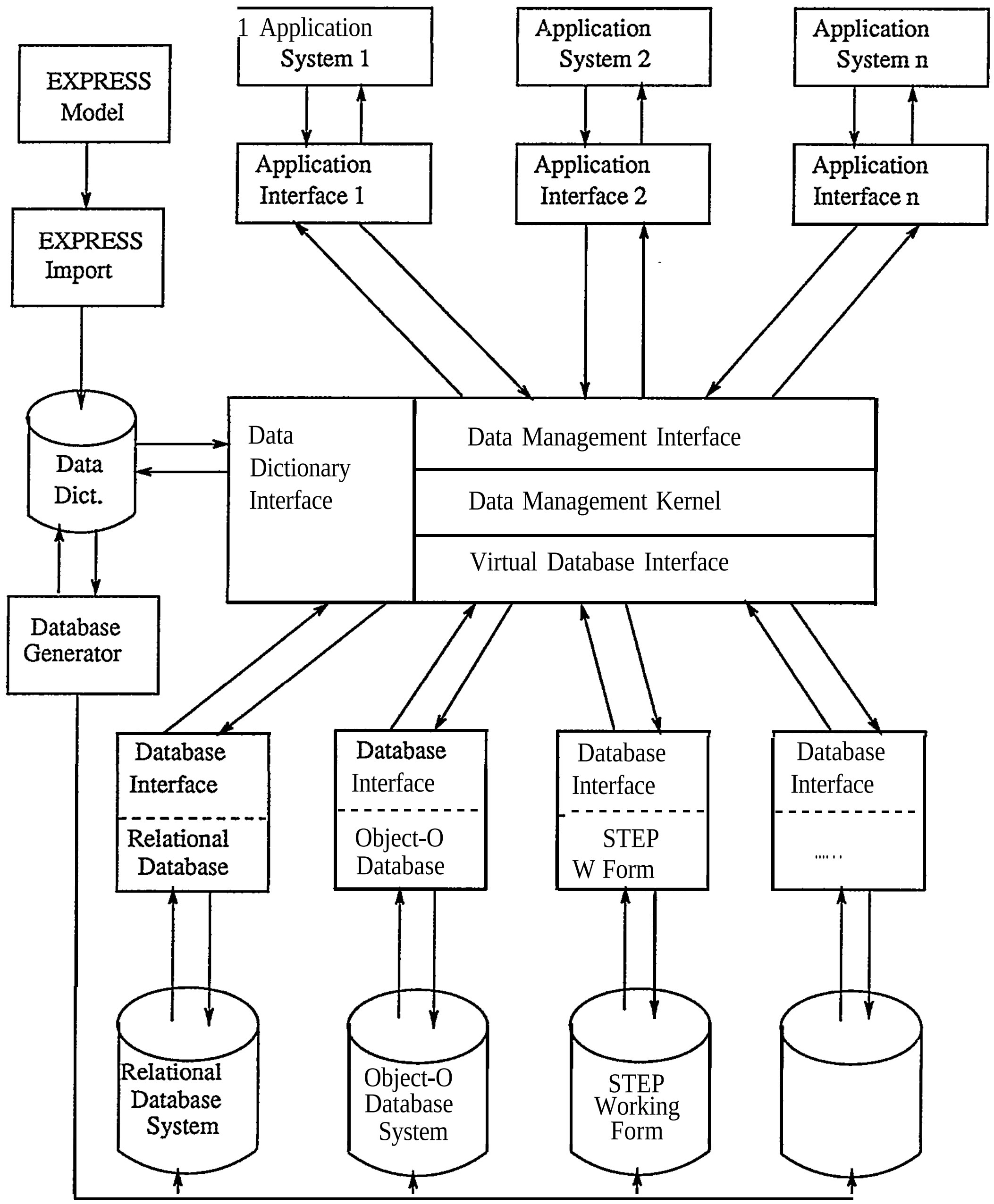

Fig.13 The NEUTRABAS system architecture.

application-independent store of product information. The main features and functions of each of these components are outlined in the following sections.

The EXPRESS model. This component of the system is the domain-specific information model which completely defines the shipbuilding product in terms of the information used to describe and represent it at each of its life-cycle stages. The model is independent of any application, and is written in the STEP information modelliig language EXPRESS. The model itself will not be static, and will continue to evolve over time.

The data dictionary. The data dictionary contains the dynamic form of the EXPRESS model described above. It comprises a formal definition of the structure of the data contained in the database, together with information concem-ing how the individual items of data are related to each other. The data dictionary allows requests to the database to be validated or it can alternatively be used to return the complete definition of the structure of an entity. This particular component can also be used to control security issues such as update rights, view rights,

versionning etc. for all of the requesting application systems.

EXPRESS import. The EXPRESS import facility is a software tool which maps from the EXPRESS-based product information model to the data dictionary defined in the above section.

The data management component (DMC). The data management component is effectively the core of the NEUTRABAS system. Its main tasks are to facilitate communication between the other components of the system and to convert requests in any one system-specific format to that of any other system. In order to carry out these tasks, the data management component consists of four main sub-components, as described below.

1. Data Management Interface - This is the external view of the NEUTRABAS system which contains a procedural interface to allow individual application systems to communicate with the neutral database.

2. Data Management Kernel - This component allows the creation, modification and querying of items of information by the connected application systems. To facilitate this, the data management kernel uses the data structure and relationship definitions contained in the data dictionary component described previously. Those requests received from the data management interface are reduced to more simple instructions by the data mangement kernel before being passed on to the virtual database interface.

3. Data Dictionary Interface - This allows the other elements of the data management component to query the data dictionary for detailed information on entities and their associated attribute structures.

4. Virtual Database Interface - This is a procedural interface which allows different database management systems (DBMS) to be connected to the NEUTRABAS system, in order to provide storage and data management facilities.

The application interface. The application interface is the specific interface which resides between a given application system and the neutral database. The interface itself may be one of two types. It may either be interactive or can simply consist of a pair of pre and post-processors, depending upon the nature of the specific application system being considered. The interface may be written in any high-level programming language providing that a suitable language binding is available.

The database interface. The database interface is the specific interface which permits communication between a particular database management system and the neutral database, and is a mapping of the virtual database interface onto an actual database system. Unlike the application interface, the database interface can utilize accepted database standards such as SQL (structured query language) for complete classes of database management systems. The database interface is a vital component of the NEUTRABAS system architecture, as it is intended that a NEUTRABAS product model will be capable of being stored in any commercial database system.

The database generator. The database generator is a tool which will map the definition of the product information model contained in the data dictionary to a specific database implementation. While performing this task it updates the data dictionary so as to provide information regarding the location of entities and their associated attributes in the actual database system. It is quite obvious that a separate database generator is required for each specific database management system being considered for connection to the neutral database. At present, consideration has been limited to the relational and object oriented database paradigms, together with the STEP working form file although it is hoped that other database types will be considered in the future.

THE PROTOTYPE IMPLEMENTATION SYSTEM

The previous sections of this paper have described various aspects of the information model of the shipbuilding product which has been developed to form the basis of the NEUTRABAS data exchange and storage system, together with a suitable architecture for the actual implementation of the system in the shipbuilding environment. In order to validate both the information model and the proposed system architecture it is necessary to perform some form of implementation to demonstrate the controlled exchange of product-related information between two or more disparate computer systems, and also to demonstrate the consistent time-independent storage capabilities of the NEUTRABAS system. Unfortunately, due to limitations on time and other resources, it is not considered feasible to implement a full version of the NEUTRABAS product model or attempt to produce all of the software tools specified in the system architecture. However, a significant subset of the complete product model specification will be implemented, as will the key software tools, in order to provide a realistic test environment for the NEUTRABAS approach.

Although the aim of NEUTRABAS is to facilitate the complete integration of all information systems in use at all of the product life-cycle

stages, for the purpose of validating the basic philosophy it has been decided to connect two, possibly three, different application systems to the NEUTRABAS system. The two definite candidates for this prototype testing system are CADIS, a steel structure design system, and CRESTA which is a production planning sytstem. The third possible candidate is a preliminary ship design system named SPAN, which will be included in the validation exercise if resources permit. Even with only two application systems it will be possible to demonstrate how systems in different application areas, each having a different view of the product, can be made to communicate in an effective manner and share common information in a coherent and consistent way. Thus demonstrating that the true goal of a fully integrated product life-cycle is indeed one which could be achieved.

As previously stated, the testing system will involve the implementation of only a sub-set of complete shipbuilding product model. This sub-set will in fact comprise part of the steel structure of the cargo region of a container carrying merchant vessel, consisting of a number of pre-fabricated production units. It is considered that the selected sub-set contains sufficient entities from the complete model to provide quite a rigorous test of the NEUTRABAS philosophy in the area of preliminary and production-oriented design, and in the complementary area of production planning and control.

The ORACLE relational database management system has been selected to provide the means for the storage and retrieval of the physical data created and used by the application systems, although in theory any relational or object-oriented database system could have been chosen. At the time of writing this paper, work is currently being carried out on the implementation of the prototype system with its completion being scheduled for March 1992.

CONCLUSIONS

This paper has described some of the work being carried out on the NEUTRABAS project in the area of neutral data exchange and storage in the shipbuilding industry. The progress outlined in this paper has demonstrated the feasibility of achieving a truly integrated shipbuilding environment through the coherent and consistent storage and exchange of information relating to the product at all of the pre-commissioning stages in its life-cycle. An information model of the shipbuilding product which will accommodate the various views and information requirements of the many computer-based systems used in the European shipbuilding industry has been described. A neutral system architecture which will facilitate the implementation of this information model and subsequently provide database management functions for the manipulation of the various product-related data created and used by the various application systems in use in the shipbuilding environment, has also been described. In addition, the proposed prototype implementation system which will demonstrate the application of the NEUITRABAS concepts in a working environment has been outlined.

NEUTRABAS is only one of many initiatives being carried out in the area of product data exchange throughout the world. It is, however, considered to be one of the leaders in this field and as such is actively contributing to the emerging international standard for the exchange of product data, STEP.

ACKNOWLEDGEMENTS

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